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THESIS

COSTS AND BENEFITS OF EXTENSIVE ELECTRICITY METERING AT THE NAVAL POSTGRADUATE SCHOOL, MONTEREY

by

Dennis L. Walton

September 1977

Thesis Advisor: CDR J. C. Tibbitts Jr.

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Center, Pt. Mugu, California forms a basis for this analysis. The analysis indicates that meters would be justified at the school if an annual savings of electricity resulting from metering could be realized in the range of 2.1% to 7.4%. The thesis concludes that similar analyses should be conducted at other Navy installations to determine the amount of electricity savings that would be required to justify metering.

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COSTS AND BENEFITS OF EXTENSIVE ELECTRICITY METERING AT THE NAVAL POSTGRADUATE SCHOOL, MONTEREY

by

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MASTER OF SCIENCE IN MANAGEMENT

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ABSTRACT

This thesis provides a brief history of utilities conservation and a background on electricity metering in the Navy. A cost analysis is made of the savings that would be required to justify installation of meters in the operational area of the Naval Postgraduate School, Monterey, California, using net present value techniques. Cost data from a metering project at Pacific Missile Test Center, Pt. Mugu, California forms a basis for this analysis. The analysis indicates that meters would be justified at the school if an annual savings of electricity resulting from metering could be realized in the range of 2.1% to 7.4%. The thesis concludes that similar analyses should be conducted at other Navy installations to determine the amount of electricity savings that would be required to justify metering.

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

Throughout the United States, consumers experienced modest increases in electricity costs from the early 1960's through the early 1970's. In fact, many large consumers, such as the Navy's shore installations, felt no real increase in electricity rates because utility companies historically used billing schedules which provided discounts for greater consumption. This tended to hold the average cost per unit of electricity nearly constant from year to year for those consumers who regularly increased their demand. Figures 1 and 2 depict total and unit cost data for the operational area of the Naval Postgraduate School for the period of fiscal year 1965 through fiscal year 1976. The nearly flat unit cost for constantly increasing demand through 1973 illustrates the result of such a billing schedule.

However, as is readily seen in figure 1, a sharp departure from the trend has occurred starting in fiscal year 1974. This change was felt Navy-wide as can be seen in figure 3. This departure was due to several factors, including sharp increases in inflation just prior to and during fiscal year 1974 as well as the Organization of Petroleum Exporting Countries' embargo.

While fiscal year 1974 created financial difficulties for those who pay electricity bills, the following years produced a new trend, as was shown in figure 2, which has caused utilities managers to become intensely interested in positively controlling and consciously reducing consumption. Out of this intense interest was spawned the Navy's

utilities conservation program of which electricity conservation is a significant portion.

In investigating the area of electricity conservation, this thesis traces the development of the Navy's present conservation program, followed by a discussion of some of the program's problems. A presentation of the metering concept and its ability to solve the program's problems is then made, and the cost of applying the metering concept is analyzed.

In this analysis, the author is taking the approach of determining what percentage of the existing electricity consumption must be saved to justify metering. This approach is used rather than trying to project the resulting dollar savings to compare against the metering costs because only inadequate data on the possible savings is available.

Finally, conclusions are made which provide guidelines for evaluating the initial concept of metering at an activity and recommendations for sources of savings information are given.

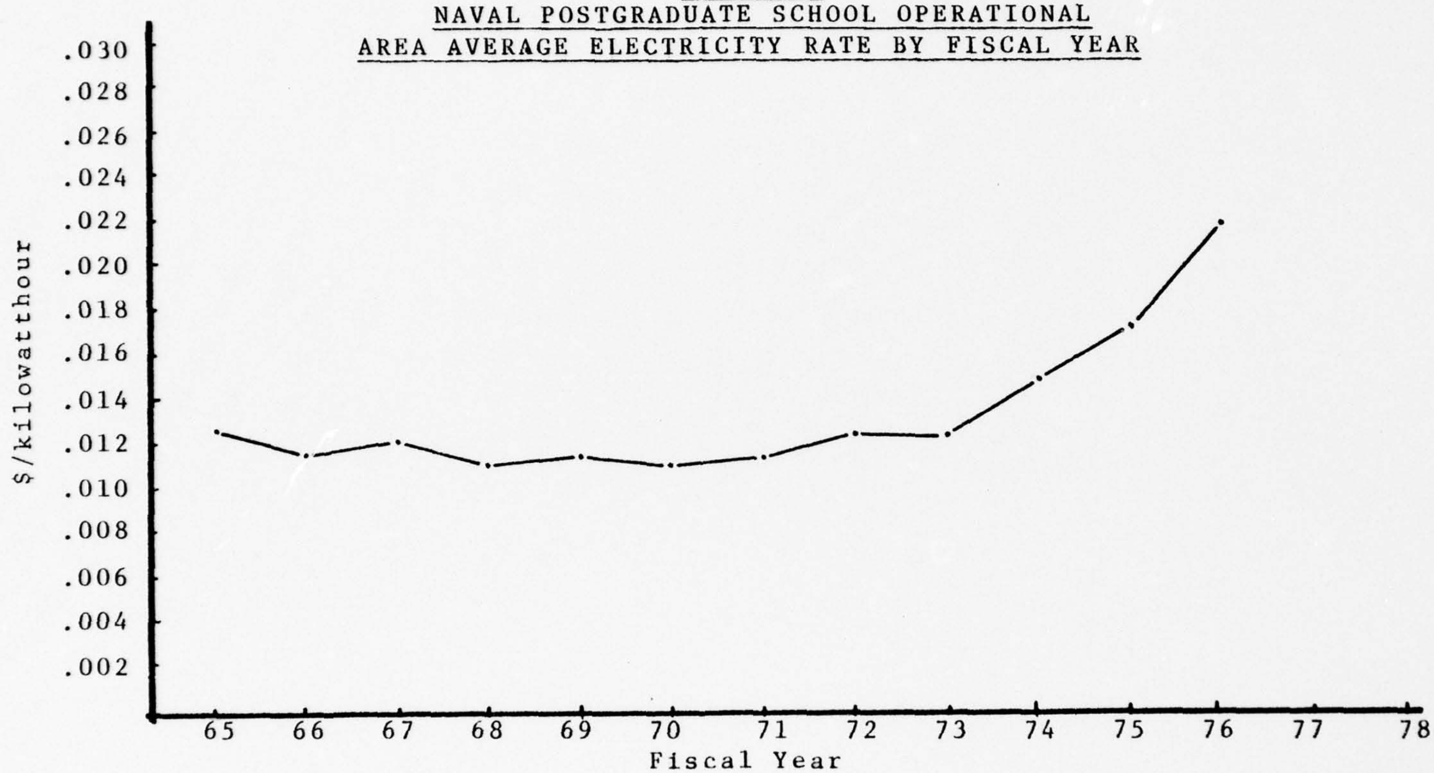
FY	KWH CONSUMED	COST	% OF PREVIOUS FY'S KWH CONSUMED	% PREVIOUS FY'S COST
65	10,118,000	$126,314	-	-
66	10,401,000	$120,596	103%	95%
67	12,058,000	$145,783	116%	121%
68	13,334,000	$149,158	111%	102%
69	13,498,000	$156,721	101%	105%
70	14,824,000	$165,674	110%	106%
71	14,897,000	$169,589	100%	102%
72	15,588,000	$191,135	105%	113%
73	16,210,900	$198,495	104%	104%
74	15,421,000	$229,147	95%	115%
75	15,130,500	$265,402	99%	116%
76	16,674,700	$356,864	110%	134%

FIGURE 1

NAVAL POSTGRADUATE SCHOOL OPERATIONAL
AREA HISTORICAL ELECTRICITY CONSUMPTION AND COST

(source: Utility Cost Analysis Reports, DEIS Reports, commercial supplier's billing information, Naval Postgraduate School, Monterey, California)

FIGURE 2
NAVAL POSTGRADUATE SCHOOL OPERATIONAL
AREA AVERAGE ELECTRICITY RATE BY FISCAL YEAR



(source: Utility Cost Analysis Reports, DEIS Reports, commercial supplier's billing information, Naval Postgraduate School, Monterey, California)

FISCAL YEAR	UTILITIES OPERATING COSTS
1971	$190 Million
1972	$208 Million
1973	$228 Million
1974	$312 Million
1975	$407 Million Including 15% conservation
1976	$457 Million Including 15% conservation

(source: Curriculum Outline for Energy Management CIN A-4a-0037; CDP9555; Naval School, Civil Engineer Corps Officers; Port Hueneme, California)

Figure 3 - NAVY-WIDE UTILITIES OPERATING COSTS: ALL APPROPRIATIONS

II. EXISTING CONSERVATION PROGRAM

A. HISTORY

Since its inception, the Navy has been forced to practice conservation. That is, the Navy has been forced to avoid waste of utilities or any other resources because of Congressional scrutiny. Also, because utilities are frequently considered an overhead item to the Navy's mission, managers have usually sought to reduce utility costs to free more of their limited funds for direct mission areas.

This situation served to invoke a waste avoidance attitude about utilities. However, because utility costs in general and electricity costs in particular were historically such small portions of the Navy's total expenditures, only minimal attention was paid to them until 1955. At that time the Bureau of Yards and Docks (BUDOCKS) issued a formal utilities conservation program for the Navy[Ref. 1]. This program drew attention to utilities consumption by establishing a utilities cost analysis report and a utilities portion for the then existing management assistance team surveys. The initial results of this program were impressive with noteworthy savings created by resolving the most obvious consumption problems. However, as the problems became less obvious and the paybacks became less dramatic, the program lost its appeal and the conservation interest it had initiated proved to be temporary [Ref. 1].

From 1955 to 1971 no new developments occurred in the utilities conservation program. Then in 1971 BUDOCKS' successor, the Naval Facilities Engineering Command (NAVFAC) revitalized the Navy's program through the issue of Naval Facilities Engineering Command Instruction 11310.19A of 27 July 1971 [Ref. 1]. In addition to refocusing attention on the program of 1955, this instruction required that a review of each activity be made during the management assistance team visits to determine if a local utilities conservation program was needed. If the local program was in order, the cognizant Engineering Field Division in cooperation with the activity was directed to develop such a plan.

Both of these programs lacked effectiveness in conserving utilities because neither established objectives which required conservation. The 1955 program and the 1971 update drew attention to utilities conservation, first at the Navy-wide level and then at the base level but neither required that individual activities reduce their utilities consumption. However, in the evolution of Navy utilities conservation, the reports required by the BUDOCKS program and the local conservation plans required by the 1971 instruction form a data and administrative base on which the present program is built.

B. PRESENT PROGRAM

This lack of emphasis on actually reducing consumption was overcome in 1974 with the issue of Federal Management Circular 74-1 [Ref. 2]. That document set as a goal a 15% reduction in utility consumption based on fiscal year 1973 use levels. This directive was implemented for the Navy by Chief of Naval Operations Instruction 4100.5 of 13 June 1974 [Ref. 3].

The Navy's approach in the conservation program for shore facilities was a two pronged attack coordinated by NAVFAC. One of these approaches was a program to encourage the development and execution of utility-conserving maintenance, repair and construction projects. Justification for and appoval of these high cost investments was based on a payback of the intial cost through projected savings in utilities in future years. While justification of projects by payback had previously been acceptable, the present conservation program allowed more favorable considerations for utility-saving projects than for other types of capital investment projects. This plan gave rise to many utility-saving projects such as the Boiler Plant Controls Rehabilitation in fiscal year 1975 at Naval Air Station, Patuxent River, Maryland and the metering project just completed at the Pacific Missile Test Center, Pt. Mugu, California.

The second area of emphasis was a consumer consciousness campaign. Through a variety of medias the Navy encouraged its people to practice utility conservation. Almost everyone who has been on a Navy base in the past few years has seen poignant messages near light switches and thermostats concerning conservation. In the area of consumer consciousness, the Navy has provided many specific guidelines regarding thermostat settings and use of utility control points. But, the real message has been that consumers of utilities, including electricity, on Navy bases must be willing to sacrifice and conserve.

C. PROBLEMS OF THE PRESENT PROGRAM

While the present program made a significant improvement in the Navy's conservation effort, it does have problems. In the area of utility-saving projects, the main difficulty has

been limited funds. In fact, the submission of these projects has been so popular that only those with the very fastest paybacks have had high enough priority to make the available funds cut-off. According to comments from the Energy Conservation Office of NAVFAC (Code 1022E), that organization is presently approving and funding projects which have payback periods of five years or less. This is quite a short period for amortizing a major investment like utility-system modifications or extensive building insulation.

While the problem of limited funds is somewhat difficult for the Navy's utility conservation managers to overcome, there are problems in the area of consumer consciousness which they can address. A major one is the lack of verifiable feedback to the responsible managers for electricity consuming activities on an individual base. Except in a few instances, such as Public Works Center, San Diego, California and Pacific Missile Test Center, Pt. Mugu, California, few electricity meters exist and they are situated to reveal the whole installation's consumption or that of several buildings or a large area within the base. As a result, the base utilities conservation manager has no ability to identify consumption in individual areas except through the use of engineering estimates. Regrettably, these estimates have been the subject of much distrust by responsible line managers. Therefore, without the ability to identify consumption within the limits of lower echelon manager responsibility, an internal waster goes undetected because of another's conservation efforts.

Another problem is that of staff impetus for the conservation program. At the individual base level, the program is usually handled within the Public Works Department which has Civil Engineer Corps officers for its leadership. With their engineering background and staff

status within the Navy-wide framework, these officers frequently have difficulty in motivating line officers and managers with their estimates and advice. As a result, there is usually a lack of involvement and impetus for the conservation program by local operational managers.

Finally, a problem exists with the inability to determine the base's electricity distribution system overhead. This again is due to the almost universal lack of meters for the end users on a base. There is virtually no way to accurately determine the amount of electricity used in street lighting and other such common functions or to know how much power is lost due to poor wiring connections and line resistance. While this system overhead almost always exists, the lack of an ability to determine it means an almost certain lack of an effort to control it.

As has been indicated, two of the three problems concerning the consumer consciousness program have been directly related to the lack of extensive electricity metering. Therefore, in an attempt to address these problems, the following discussion of metering is presented.

III. METERING, A CONCEPT FOR CONSERVATION

A. BACKGROUND

There is growing sentiment that meters are necessary for internal control of utilities within DoD. In May of 1977 it was reported that the House of Representatives Sub-Committee on Military Installations and Facilities was prepared to direct the military services to install meters on all family housing units [Ref. 4]. Also, the Army Audit Agency, in a report on the Army's Energy Conservation Program, specifically identified consideration of meters as important [Ref. 5]. While both of these groups acknowledged that the conservation publicity campaign has been effective in reducing consumption, they both indicated a feeling that further reductions would follow the metering.

B. DESCRIPTION OF THE METERING ADDITION

As an addition to the present conservation campaign, electricity meters can be used to measure and identify consumption in a particular area. Generally, these meters would be installed throughout the shore facility to measure the electricity used in areas which coincide with manager responsibility and authority. Once installed, data from these meters will be periodically collected and valid documentation of consumption by area will follow.

After this consumption information is recorded, it can be employed in two ways. First, comparisons with similar previous and present information can be made and thus responsible area managers' performances can be evaluated. Second, the shore facility can establish a billing system, much like commercial utility companies, and charge responsible managers for electricity consumed by their areas. In this case, Public Works Departments would have to alter their roles to that of billing agent and expert advisor rather than base-wide electricity procurer. Obviously, budgeting for utilities would shift from Public Works to the managers who would have to pay the bill.

In either case, the meters provide reliable feedback to the base managers. No longer can the electricity waster ride undetected on the efforts of the conserver. Also, assuming that a base-wide meter exists, system costs such as line loss, street lighting and other common electricity uses can be determined. With valid consumption data available and with that data determining the area manager's ratings, it is believed that more goal congruence will exist between an operational manager's present objectives and electricity conservation. This goal congruence should provide self-induced motivation to conserve and should cause the conservation publicity campaign to originate with line managers rather than staff officers. Also, the area manager's increased conservation emphasis should lead to a take over of conservation monitoring and control by line management. Therefore, the conservation program should gain more support, especially at the lower organizational level and should, consequently, be even more successful than the present staff supported campaign.

It is upon the basis of this goal congruence and the resulting increased conservation that the metering addition would be justified. However, because no data concerning

actual savings resulting from extensive metering exists, there is a lack of documented support or denial of these intuitively reasonable projections. The Naval Facilities Engineering Command does indicate that in a somewhat analagous situation, the installation of individual apartment meters in a complex which theretofore had only a single meter typically results in a 25% savings for the whole complex [Ref. 6].

All of these advantages over the existing conservation program do have counterbalancing disadvantages which must be considered. Obviously, the cost of purchasing and installing an extensive metering system is significant.

In fiscal year 1977, the Commanding Officer of the Naval Training Center, San Diego, California voiced doubts concerning the engineering estimates for that command's electricity consumption. In response, the cognizant Public Works Center (PWC) suggested that metering might help by providing direct consumption measurement. PWC, San Diego, California estimated the cost of installing 22 electricity meters to monitor the Naval Training Center's consumption at about $1,500 per meter [Ref. 7]. While it is admitted that this is an extreme example, an estimate of "... several hundred dollars ... minimum for metering a typical Navy building," is suggested [Ref. 7]. Because of the unusually high cost for this particular metering project, no action was taken beyond the estimating stage.

More definite cost estimates can be gleaned from data concerning a recent project at the Pacific Missile Test Center, Pt. Mugu, California. In a project very similar to the concept discussed in this section, that Navy shore facility installed 146 watt hour meters at a contract cost of approximately $114,000. This quotation was obtained from the Pacific Missile Test Center Energy Conservation Officer

(Code 6200-3). However, additional charges of 6% of contract cost for supervision, inspection and overhead from the contract administering command brought the total cost for the project to about $121,000 or $830 per meter.

This project included the installation of meters on all distribution sub-stations and on almost every non-housing structure which has electricity service on the base. The purpose of these meters was two-fold. First, they were to put aside the doubts concerning engineering estimates and second, they were to encourage electricity conservation through feedback to responsible managers. The completion of the project in late 1976 satisfied the first purpose of obtaining direct electricity use measurement. However, because the management information system which relays the consumption data to the responsible managers is not yet fully operational, conservation results have not yet occurred.

While a meter can be purchased for about $70 to $400, the majority of the costs in both projects cited is due to the modifications required to the existing wiring to accommodate the meters as indicated by reference 7 and the Pacific Missile Test Center Energy Conservation Officer.

Along with the intial cost of installing the meters, the base must bear the administrative costs of using them. These include the cost of reading the meters, documentation and analysis of those readings, and maintenance of the meters and the management information system.

Another important difficulty with metering is the inability to determine, from readings, the electricity consumed by each organizational entity when the metered area is shared amcung multiple occupiers. Then responsibility must be determined by estimates and room for doubt

concerning conservation performance results. For this reason, the metering must be extensive enough, within a building if necessary, to identify consumption on an organizational level low enough to avoid significant combined responsibility by internal base and command managers.

Finally, a significant problem area is that of electricity distribution system overhead. Obviously, line loss, street lighting, and other costs of operating a distribution system must be considered. The question arises, how much system overhead will the metered managers consider reasonable? This is especially important if the area managers are paying for electricity directly at a rate which would include system overhead costs as well as generation or purchase cost. This scrutiny of system overhead may have the beneficial effect of insuring more favorable support by the line managers for Public Works projects and programs to improve and maintain the base's distribution system.

To provide the conservation program decision makers with a real world example, the following sections provide an analysis of this metering plan as it applies to an existing Navy facility.

IV. APPLICATION OF METERING TO THE NAVAL POSTGRADUATE SCHOOL, MONTEREY, CALIFORNIA

Before discussing the details of the application of metering to the Naval Postgraduate School, a brief description of the installation is provided. The facility covers approximately 600 acres of land with a variety of structures. It is located on what was the grand Del Monte resort of the late 1800's and early 1900's. While some of the resort's buildings dating from before 1900 remain, others were completed as recently as 1975. The school is divided into five parcels of land; the main station, the La Mesa Village housing area, the beach area, the lab-recreation area and the annex. Each parcel has a separate internal electricity distribution system with at least one metered supply from Pacific Gas and Electric Company, a commercial utility. On these five parcels are 526 structures and improvements, including 372 housing structures. A majority of these 526 structures have electricity service. Electricity is used for lighting, cooling and various equipment power supply, while natural gas is the prime energy source for heating.

The scope of this thesis is intended to cover only the non-housing areas since Congress is already prepared to direct the military services to install meters in housing areas. With that situation, it is felt that a study of housing metering would be an exercise in hindsight rather than an example for decisions yet to be made. Therefore, the 372 housing structures were omitted from this study leaving 154 buildings and improvements to be investigated.

After study of property records [Refs. 8 and 9] and interviews with Public Works Department personnel, it was discovered that 73 of the 154 non-housing structures would require no meters. This was due to lack of present or planned electric service, planned demolition, or the current existence of meters (total of 20). However, because some of the 81 buildings and improvements which required meters were divided amcung several organizational units, it was estimated that 100 meters must be added to the school to apply metering in a fashion consistent with that described in the preceding section. With the existing 20 meters, this addition would bring the total number of internal electricity meters to 120 for the non-housing areas of the school. Appendix A indicates the proposed locations for the 100 additional meters.

V. ECONOMIC ANALYSIS OF THE METERING CONCEPT

The following analysis is an attempt to give decision makers a feel for the relative merits of metering. Because no applicable data concerning savings of electricity after extensive metering is available, the normal procedure of a cost/benefit analysis has been modified. In this thesis the lifetime costs of the metering concept have been estimated and converted to their net present value using the recommended 10% discount rate [Ref. 10]. The details of the cost estimate are provided in Appendix B. Also, the cost of electricity based on constant consumption using fiscal year 1976 as a base-line is extended through the same periods as the proposed economic lifetimes of the metering project. The total estimated future cost is then converted to net present value by means similar to those used for the metering concept. This second net present value represents the cost in today's dollars of continuing to use electricity as it is presently used with only the benefits of the existing conservation program. These net present value analyses are detailed in Appendix C. Finally, the net present value of the metering concept is computed as a percentage of the net present value of the unaltered electricity consumption over similar future periods. The resulting percentages indicate the average annual savings as a part of future electricity costs necessary to pay back the cost of the metering addition during the future period.

Because of the effect of inflation in long payback period projects and because of its variability, differing considerations for inflation have been made. In Case 1 (see Fig. 5 of Appendix C), different inflation rates have been

applied to the metering and the electricity costs for the first five years. An estimate of 15% for the annual inflation index for electricity costs over the next five years has been provided to the author [Ref. 11], while metering costs are expected to increase at an estimated inflation rate of 6.8%. Effects of inflation after the initial five year period have been considered identical on both the metering and the electricity costs in Case 1.

In the final case analyzed, Case 2 (see Fig. 6 of Appendix C), it is assumed that inflation will affect both electricity and metering costs at the same rate for any future period so the effect of inflation is disregarded.

Two time-spans have been investigated within each case. First, an economic life of five years is established, to match the existing maximum payback time for approved and funded energy conservation projects. Next, since the real economic life of electricity meters is estimated at 40 years or more [Ref. 12], an analysis using a 40 year project life is included in both Case 1 and Case 2.

The results of this thesis show that if differential inflation is applied as in Case 1, a savings of 5.2% over five years or 2.1% over 40 years must occur to pay back the additional costs if the Naval Postgraduate School installed meters to improve its electricity conservation program. Similarly, the results of Case 2 indicate that the school must realize an average annual savings in future electricity costs, of 7.4% over five years or 3.6% over 40 years to recapture the cost of the meters if inflation is disregarded. Obviously, if savings greater than these would result, metering costs could be recovered more rapidly. Conversely, lower savings imply a loss on the investment for meters.

The results discussed above would indicate that metering analysis for any particular activity would be appropriate if savings in the range of 2.1% to 7.4% are estimated as feasible.

VI. CONCLUSIONS

In deliberating over the question of extensive metering, the cognizant local decision maker at any activity must consider which economic life or payback period is appropriate. The 40 year period should be most applicable if the intial cost of a particular metering project is expected to fall within local approval authority limits. However, if the size of a base metering project forces referal to reviewing offices above the command, then the fastest payback possible is desirable. In that case, the local managers should direct their thinking and analysis to the five year period.

No matter which payback period seems reasonable, the conclusions of this thesis provide the below listed guidelines.

A. If the local decision maker feels that an average annual savings of electricity costs of 5.2% to 7.4% over five years is feasible, then a metering project for that particular installation should be analyzed in a manner similar to Appendix C and should be pursued if the analysis supports such action.

B. Should the local situation indicate the 40 year lifetime as reasonable, then the local decision maker should feel sure of an average annual savings of 2.1% to 3.6% before spending time and money on a full analysis of metering for that locality. However, the local decision maker is cautioned to consider very carefully the effects of a 40 year projection. There is significantly more room for error, especially by compounding small differences

between the projected and actual situation than with a shorter time-span.

C. If the savings identified relative to the situations described above are not considered reasonable at a particular base, then no further consideration of extensive metering should be made for that locality until the expected savings rise to the appropriate level.

D. Should extensive metering be warranted, it is recommended that the manager performance review concept be employed with the introdution of the meters rather than the billing system. Because metering will bring such a significant change to the base's electricity supply system, it is considered that simultaneous implementation of a billing plan would compound the problems that naturally come with change. If considered necessary, it is recommended that internal billing be incorporated at a later time.

In order to lift some of the burden of guessing the future savings of metering from the local decision maker, the following suggestions for obtaining information on that matter are submitted.

A. A follow-on study can be performed by direct, limited scope experimentation. The employment of a small number of meters can be made to measure portions of a base's consumption. Through an extended delay in announcing the installation of the meters, before and after data may be obtained. This plan will require much time and careful design of the experiment.

B. Another more reliable source of savings information would be the investigation of the Pt. Mugu consumption trends after a history of data relative to the recently installed extensive metering is established.

C. The 25% savings resulting from metering an apartment complex as cited by NAVFAC and discussed in an earlier section of this thesis can be used as a rough guide. However, several differences between that situation and the metering of a Navy base under this study's assumptions exist. First, the apartment situation includes residential activities while the operational areas of a Navy installation are more similar to commercial or industrial functions. Second, no indication of the time in history of metering the apartments is given. They may have been installed long before our nation's current energy consciousness and conservation trends began. Third, it is presumed that with the new apartment meters, the tenants were required to pay electricity bills for the first time in that complex. With the manager review plan, no analagous situation exists. Fourth, no indication as to the length of this 25% savings was made and there is no reason to believe that such a reduction would or would not last the full projected payback period.

Finally, there are some intangible benefits of metering which the local decision maker may want to consider.

A. The installation of electricity meters provides not only a means for positive management control of electricity use but further sets the stage for such control in other utilities. It establishes in the minds of the local consumers the idea of higher management scrutiny of their utility consumption. Metering and the manager review process will also familarize the responsible consumers with the kinds of tactics they must employ to respond to the review and to conserve utilities.

B. With some modifications, electricity meters can be used as point sensors in a system which monitors and controls demand peaks. Since these demand peaks have a significant

effect on future electricity rates, control of them is becoming increasingly desirable.

APPENDIX A

PROPOSED LOCATIONS FOR ADDITIONAL METERS

The following table identifies the proposed locations of 100 new electricity meters at the Naval Postgraduate School, Monterey, California.

STRUCTURE NUMBER	STRUCTURE NAME OR FUNCTION HOUSED	METERS ADDED
15	ONI,DOD	1
21	CPO Mess	1
22	NEPRF	1
24	Supply and Fire Station	1
25	Child Care Center	1
27	Storage	1
64	Storage	1
74	Storage	1
98	Fueling Stand	1
99	Transmission Tower	1
102	Instrument Stand	1
186	P. W. Maintenance Shop	1
188	Water Storage Tank	1
189	Water Pump House	1
191	Golf Course Clubhouse	2

STRUCTURE NUMBER	STRUCTURE NAME OR FUNCTION HOUSED	METERS ADDED
192	Tractor Garage and Maintenance	1
194	Chlorinator Building	1
195	Toilet Building	1
197	TW Systems Building	1
199	Golf Course Pro Shop	1
200	Computer Center, FNWC	1
203	Offices, FNWC	1
205	Barracks, WEQ	1
211	EM Recreation Hall	1
213	Cascade and Turbine Lab.	1
214	Engine Maintenance Shop	1
215	Compressor Lab.	1
216	Jet Engine Lab.	1
217	Rocket Motor Lab.	1
218	Marine Biology Lab.	1
219	Gate, Sentry House	1
220	Herrmann Hall	14
221	Herrmann Hall, East Wing	4
222	Herrmann Hall, West Wing	2
230	Aeronautical Lab.	1
231	Radar Tower	1
232	Spanagel Hall	1
233	Electrical Engineering Lab., Bullard Hall	1
234	Halligan Hall	1

STRUCTURE NUMBER	STRUCTURE NAME OR FUNCTION HOUSED	METERS ADDED
235	Root Hall	1
236	Central Heating Plant	1
237	King Hall	2
240	Electric Switchgear Building	1
241	Sewage Pump Station	1
242	Auxilary Sewage Pump Station	1
243	Electronic Equipment Building	1
244	Swimming Pool Pump House	1
246	Double Handball Court	1
247	Boiler EM Building	1
248	Muffler Stack Building	1
249	Jet Test Building	1
250	Swimming Pool	1
251	Swimming Pool	1
252	Double Tennis Court	1
256	Swimming Pool Filter Building	1
257	Condensate Pump House	1
258	Fire House	1
259	Barracks, EM	1
260	Subsistence Building	1
287	Water Storage Tank	1
288	Water Pump Station	1
291	Toilet	1
292	Steward's Quarters	1
296	Mobile Antenna	1

STRUCTURE NUMBER	STRUCTURE NAME OR FUNCTION HOUSED	METERS ADDED
297	Antenna Field	1
327	Fuel Storage Tanks	4
329	Sewage Pumping Station	1
330	Ingersoll Hall	1
333	Incinerator	1
338	Booster Pump	1
339	Library	1
340	Golf Course Storage Building	1
343	Water Storage Tank	1
345	Booster Pump	1
412	Closed Circuit TV Building	1
500	Interim Mechanical Engineering Lab.	1
514	Interim Ocean Sciences Lab.	1
518	Transformer Building	1
	Total Meters to be Added	100

APPENDIX B

COST ESTIMATE FOR METERING CONCEPT

The following discussion describes the assumptions and methods applied in the development of a lifetime cost estimate for the metering concept as it applies to the Naval Postgraduate School. First, a generalized description of costs is made and then the sources of the numbers and an explanation of the computations is provided for each line of the summary shown in Figure 4.

The costs have been broken into two categories. The first is the one-time or investment costs of the concept. The second category includes all those costs which are due to the existence of the meters and which will occur annually as long as the meters are used.

The most significant cost is the investment required for purchasing and installing the electricity meters. In estimating this cost an average of $830 per meter installed is used. That amount was derived by finding the average cost per meter in the Pacific Missle Test Center, Pt. Mugu project for extensive metering. There are several reasons for accepting that figure. First, the Pt. Mugu project provided a similar number and density of meters on that installation as is proposed by this analysis. Second, both bases have similar distribution system voltages. Third, the costs are current since the project was completed in late 1976. Fourth, the Pt. Mugu average is in line with estimates provided by Public Works Center, San Diego,

California [Ref. 7] and with quotations cited by Pacific Gas and Electric Company [Ref. 11]. Fifth, the Pt. Mugu installation is relatively close to the Naval Postgraduate School and therefore the differences in cost due to geographical characteristics are minimized.

The only other one-time cost is that estimated for the design and implementation of a management information system (MIS) software package. It is assumed that this system will be computer based and will be the main tool for translating meter readings into meaningful manager review information. The estimate is based on an interview with the Director of the W. R. Church Computer Center (Naval Postgraduate School Code 01441). He indicates that six man-months for a GS-9 programmer for this type program is sufficient. The program as conceived and estimated, accepts the meter readings and performs arithmetic manipulations and trend analyses on them. This estimate was confirmed by Public Works Center, San Diego, California Utilities Division Office (Code 680) which works with a similar system.

The recurring annual costs are almost exclusively labor costs and all are based on current 1977 rates which coincide with year one of the analyses in Appendix C.

An obvious recurring cost is that of reading the meters. Since the school now has 20 meters and reads them monthly, the author interviewed the supervisor of the meter readers for an estimate. His estimate was that a meter reader could read 60 meters on the base in an eight hour day. That estimate includes physically reading the meters plus formatting the data for keypunch translation. Since this thesis proposes a total of 120 meters for the school, an effort of 16 man-hours per month will be required for reading the meters. Futher investigation within the base's Public Works Department revealed that the present pay rate

for the meter readers is $9.18 per hour which includes fringe benefits [Ref. 13]. Materials for meter reading were considered negligible.

The estimate for keypunching these readings for entry into the MIS was provided during the interview with the director of the computer center. His quotation of one hour per month for the 120 data points with a rate of $3.75 per hour was deemed adequate, while annual materials cost for keypunching was estimated at $50.

The director of the computer facility further indicated that while in a Navy situation, the computer run costs would not usually be charged against the conservation program, an estimate of $50 per month would cover such a cost if the MIS were run in a commercial facility. This amount was included in the annual operating costs used in this analysis.

While the manager review plan, as described in the body of the thesis, will probably be managed by military personnel, an attempt was made to estimat5 385 3ost of their efforts. It was assumed that a monthly review of the MIS print-out would be performed by the school's Energy Conservation Officer. It is estimated that that officer would spend one hour per month in review and analysis and in writing a summary report for the base-wide superior, presumably at the executive officer level within the school. It is further estimated that the executive officer, at the rank of Captain, would spend approximately three hours per quarter reviewing and analyzing the reports and in conducting the manager review. The hourly composite rate for a Lieutenant (junior grade) (Energy Conservation Officer) is $8.07 while for a Captain it is $17.39 [Ref. 14].

The last cost item, maintenance of the MIS, is estimated

at a lump sum of $1,000 or almost one man-month per year for a GS-9 programmer. This item is for adjustments to the software for user compatability and for updates in output requirements as indicated by the school's computer center director.

There are some items of very small or intangible cost which were considered but were not included in the estimate. One such item is the cost of maintaining and repairing the electricity meters. In an effort to obtain data on this item the author contacted the local electricity supplier. Pacific Gas and Electric Company indicated that their cost in this area was so insignificant that they had no system for tracking or controlling it [Ref. 11]. The utility company went on to say that with a secured area like the base, the relative cost of meter maintenance should be even less than those which they experience [Ref. 11]. This was felt because the supplier's prevailing reason for repairing the meters has been vandalism. Therefore, the maintenance and repair cost for the meters is not included in the estimate.

Another item of cost considered was the amount of electricity consumed by the meters but not registered on them. Since that is estimated at two watthours per month per meter [Ref. 11], the total amount consumed would be less than 250 watthours per month for all 120 meters. In view of a cost of $0.021 per kilowatthour (1,000 watthours) and a total bill of $356,864 for fiscal year 1976 in the operational area of the school (Fig. 1 and 2), this item was considered to be insignificant.

Finally, the cost of distributing the MIS reports and manager review memos is considered to be intangible since it is assumed that the base guard mail will fill the function.

I. ONE-TIME COSTS

Installation of Meters $830/meter x 100 meters	$83,000
Design and Implementation of Management Information System $1,250/man-month x 6 man-months	$7,500
Total one-time costs	$90,500

II. RECURRING ANNUAL COSTS

Meter Reading $9.18/man-hour x 16 man-hours/month x 12 months/year	$1,762
Key Punching $3.75/man-hour x 1 man-hour/month x 12 months/year + $50 materials	$95
MIS Computer Run $50/run x 1 run/month x 12 months/year	$600
Manager Review Plan $8.07/man-hour x 1 man-hour/month x 12 months/year + $17.39/man-hour x 3 man-hours/quarter x 4 quarters/year	$306
Maintenance of MIS $1,000 lump sum	$1,000
Total recurring annual costs	$3,763
Rounded to	$3,770

Figure 4 - SUMMARY OF METERING ESTIMATE

APPENDIX C

PRESENT VALUE ANALYSES OF COSTS

Through the net present value technique, the costs of the metering concept and those of the Naval Postgraduate School's electricity consumption are analyzed.

In Case 1, as shown in Figure 5, the effect of differential inflation rates for the project and electricity costs is considered. However, because of the uncertainty of the inflation index estimates beyond five years into the future, Case 1 only applies the differing rates for the first five years of the analysis. Those rates are stated and explained in the below discussion of assumptions and calculations.

Within Case 1, two time-spans are investigated because of their relative importance in the local activity situation. First, a five year life is studied because that is the existing maximum payback period of the conservation projects which are presently being funded. Second, because estimates indicate that electricity meters will last at least 40 years, that time-span is used for a second project lifetime.

In Case 2 as shown in Figure 6, it is assumed that inflation will affect all the costs in the analysis in the same proportion and inflation is therefore ignored. This case forms a base-line for considering metering when the local utilities conservation decision maker either doubts

the validity of the indices used in Case 1 or believes that the inflation rates applicable to his or her activity differ from those in Case 1.

As in Case 1, Case 2 includes analyses of the five year and 40 year project lifetimes for similar reasons.

In both cases, the costs of metering are based on Appendix B while the basic electricity costs are found in Figure 1. These basic costs are adjusted by the applicable inflation factors in Case 1 before the net present value analysis begins.

In both cases, the net present value of the metering project's lifetime cost is determined by applying the recommended discount factor for each part of the lifetime. These discount factors are based on a 10% discount rate for public investments as suggested in Reference 10. The net present value of the unaltered electricity consumption for the school, based on the 1976 volume and extended over similar time-spans as the project lifetimes, is determined similarly. Then the net present value of the project cost is divided by the net present value of the electricity costs for similar periods in both cases. This establishes the proportion of the electricity costs which must be saved on an average annual basis to pay back the metering costs.

The following assumptions and explanations are presented concerning the computations shown in Figures 5 and 6.

1. Project year zero of all the analyses is fiscal 1976 due to the lack of audited data on the school's electricity consumption for later periods. Also, this is the time-frame of the Pt. Mugu project which forms the basis for a significant part of the year zero costs.

2. Because an annual inflation rate of 15% for electricity

costs for the school for the next five years is estimated [Ref. 12], that percentage is applied to the appropriate cost items in Case 1.

3. An annual inflation rate of 6.8% is applied to the metering concept costs in Case 1. That rate was estimated by a series of manipulations of data concerning inflation indices for such costs. Since only the recurring costs merit the application of inflation rates and since they are almost entirely labor costs, the following method for obtaining the 6.8% rate was used. First, the labor efforts were divided into two broad categories, skilled maintenance for the meter readers and professional, administrative and technical support for all others. Second, since no data by inflation indices could be located for skilled maintenance labor for years 1975 and 1976, a five year average annual rate was established using 1974 and prior data [Ref. 15]. That average was found to be 6.84%. Third, a similar average for the professional category was established at 6.76% with the aid of pertinent data starting with 1976 and moving back through 1972 [Ref. 16]. A weighted average of these two indices was then established by the following computation: $[1762/(1762 + 1351)] \times 6.84\% + [1351/(1762 + 1351)] \times 6.76\% = 6.78\%$, rounded to 6.8%. The 1762 is the annual cost of meter reading and the 1351 is the sum of the keypunching labor cost, the manager review plan costs and the MIS maintenance costs [Fig. 4]. No five year stream of inflation indices for computer run time was found.

4. Individual discount factors for years zero through five are taken from table E-16 of Reference 17.

5. The combined discount factor for years one through five is taken from that same table and is simply the sum of the individual factors for those years.

6. The combined discount factor for years six through

forty is computed using the same table and as follows: the combined discount factor for years one through forty minus the combined discount factor for years one through five.

7. The costs shown for years six through forty is a constant annual cost, not the total for those 35 years.

8. Net present value is computed by multiplying the projected cost occurring annually in each period times the corresponding discount factor.

PROJECT YEAR	NPV FACTOR	ELECTRICITY COST	ELECTRICITY NPV	METERING COST	METERING NPV
0	1.0000	N/A	N/A	90,500	90,500
1	0.9091	410,394	373,089	3,770	3,427
2	0.8264	471,953	390,022	4,026	3,327
3	0.7513	542,745	407,674	4,300	3,231
4	0.6830	624,157	426,299	4,593	3,131
5	0.6209	717,781	445,670	4,905	3,045
6-40	5.9880	717,781	4,298,072	4,905	29,371
Total NPV Years 0-5			2,042,844		106,667
Total NPV Years 0-40			6,340,916		136,038

Five Year Payback Percentage

$$\frac{\text{Total NPV Metering Years 0-5}}{\text{Total NPV Electricity Years 0-5}} = 5.2\%$$

Forty Year Payback Percentage

$$\frac{\text{Total NPV Metering Years 0-40}}{\text{Total NPV Electricity Years 0-40}} = 2.1\%$$

Figure 5 - CASE 1: NET PRESENT VALUE ANALYSIS OF ELECTRICITY AND METERING COSTS WITH INFLATION APPLIED

PROJECT YEAR	NPV FACTOR	ELECTRICITY COST	ELECTRICITY NPV	METERING COST	METERING NPV
0	1.0000	N/A	N/A	90,500	90,500
1-5	3.9771	356,864	1,419,248	3,770	14,993
6-40	5.9880	356,864	2,136,902	3,770	22,575
Total NPV Years 0-5			1,419,248		105,493
Total NPV Years 0-40			3,556,150		128,068

Five Year Payback Percentage

$$\frac{\text{Total NPV Metering Years 0-5}}{\text{Total NPV Electricity Years 0-5}} = 7.4\%$$

Forty Year Payback Percentage

$$\frac{\text{Total NPV Metering Years 0-40}}{\text{Total NPV Electricity Years 0-40}} = 3.6\%$$

Figure 6 - CASE 2: NET PRESENT VALUE ANALYSIS OF ELECTRICITY AND METERING COSTS WITH NO INFLATION APPLIED

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